# Influence of the V-Y advancement flap geometry on the wound closure maximal force

Djamel Remache, Kévin Billon, Florian Gallecier, Julien Pauchot, Jérôme Chambert, Emmanuelle Jacquet

# Influence of the V-Y advancement flap geometry on the wound closure maximal force

D. REMACHE[1], K. BILLON[1], F. GALLECIER[1], J. PAUCHOT[2,3], J. CHAMBERT[1], E. JACQUET[1]

[1] *University of Franche-Comté, FEMTO-ST Institute - UMR 6174 CNRS, Department of Applied Mechanics, 24 rue de l' Epitaphe, 25000 Besançon, France*

[2] *Orthopedic, Traumatology, Plastic Reconstructive and Hand Surgery Unit, University Hospital of Besançon, Place Saint Jacques, 25030 Besançon, France*

[3] *Research Unit, EA 4268 I4S IFR 133 INSERM, University of Franche-Comté, 25030 Besançon, France*

*Keywords:* Non linear elasticity; VY-advancement flap; Finite Element Method; Human skin

## 1 Introduction

In clinical practice, the V-Y advancement flap is a widely used technique to cover human skin defect, which consists in incising; advancing and suturing a triangular flap adjacent to the base of a rectangular defect (see Figure 1a).

A previous geometrical study of the V-Y flap technique allowed us to find a good compromise between the flap size and the defect width [1]. However, the geometrical approach does not consider the mechanical properties of the human skin by assuming rigid-body behaviour of the skin. The aim of the present paper deals with a numerical analysis as a complement to the geometrical one to highlight the major role of the skin elasticity in the V-Y advancement flap. A compromise between the size of the flap and the level of the closure force value has been found when varying the angle at the flap apex, noted θ. The sensitivity to the mechanical parameters makes the closure force dependent on the size to be covered. At the end, the successive actions of the surgeon are analyzed.

## 2 Methods

The V-Y advancement flap technique is detailed in [1]. In the present study, we put the emphasis on the most critical phase of the V-Y advancement flap which consists in suturing the stitch from position $N_{ortho}$ to the position O*'* (the flap apex) as shown in Figure 1c. The high closing tensions during this phase could cause a skin necrosis at the apex of the flap after suturing [2].

The loss of substance is a rectangular hole of 20 mm-wide and 40 mm-length within a planar human skin area (200 mm × 140 mm) which is supposed to come from the abdomen region with 1 mm-skin thickness.

The skin was modelled as a homogeneous, incompressible, hyperelastic and isotropic material described by a one-term Ogden model [3]:

$$W = \frac{2\mu}{\alpha^2}\left(\lambda_1^\alpha + \lambda_2^\alpha + \lambda_3^\alpha - 3\right) \tag{1}$$

where $W$ is the strain energy density per undeformed unit volume, $\alpha$ is a strain hardening exponent; $\mu$ the shear modulus under infinitesimal straining; and $\lambda_1$, $\lambda_2$ and $\lambda_3$ are the principal stretch ratios.

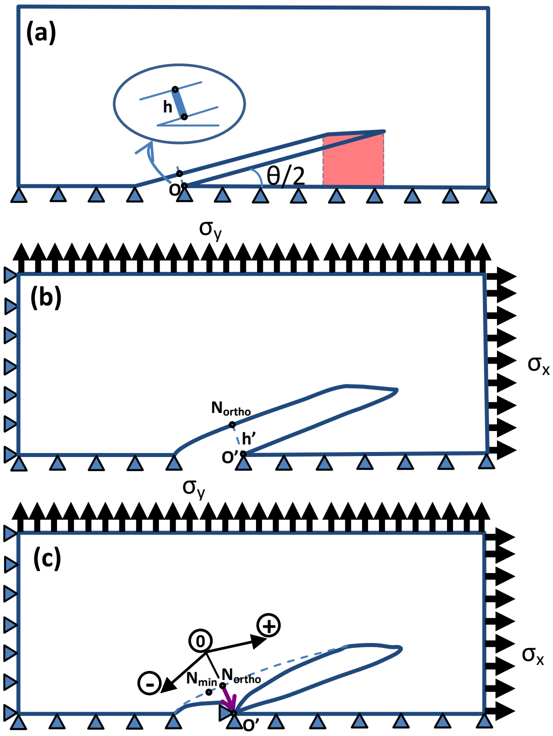


Figure 1 Profiles of the V-Y flap with apex angle θ = 30°. (a) Initial geometry (b) Intermediate step: pre-stressed domain (c) Final step: superimposing a prescribed displacement

The material parameters were identified from *ex vivo* test performed on abdominoplasty human skin: $\mu$ = 34.3 kPa and $\alpha$ = 13.46 (unpublished results). The horizontal axis coincides with Langer's line direction in the abdominal area. However, note that the anisotropy has been neglected. The values of the biaxial pre-stress are $\sigma_x$ = 5.5 kPa and $\sigma_y$ = 1 kPa.

The numerical simulations were carried out with Ansys® v12 software by using 2D finite elements (PLANE183) under plane stress hypothesis.

Due to the symmetry of the problem, only half of the domain is modelled (see Figure 1). First, a biaxial loading was applied to the geometric model (Figure 1a) to simulate the pre-stress state. So the domain is deformed and new dimensions of the defect and the flap are shown in Figure 1b. In particular, the initial width h of the defect becomes h'; the location of the flap apex moves from O to O', and its orthogonal projection on the opposite edge of the defect is the $N_{ortho}$ point.

Second, an imposed displacement is applied to simulate the wound closure (Figure 1c). The node N to be joined with the flap apex O' is chosen next to $N_{ortho}$ and moved to its target. The corresponding closure force noted R (Table 1) is then calculated for various geometries of the V-Y advancement flap (values of θ-angle in the 20° - 60° range).

## 3 Results and Discussion

As it was expected [1], the closing force is greater if the flap angle value is larger even if the width of the skin defect to cover is not the determining factor as the geometric analysis let predict. This is consistent with the surgeon's practice which is used to fit the flap technique according to the wound location and the skin elasticity. Furthermore, pre-stress state and skin rigidity are the main factors to consider for minimizing the closure force. Usually, after checking that the V-Y advancement flap is usable and suitable, the surgeon evaluates a compromise between the flap size and the closure force. Sometimes, for instance if the skin is too stiff and under high tension, the surgeon designs a longer flap (θ-angle close to 20°) to ensure closure without any complication such as necrosis [2].

| Angle θ (°) | 20 | 30 | 40 | 50 | 60 |
|---|---|---|---|---|---|
| **h (mm)** | 3,47 | 5,17 | 6,84 | 8,45 | 9,23 |
| **h' (mm)** | 5,93 | 7,37 | 9,02 | 10,68 | 12,33 |
| **$R_{ortho}$ (N)** | 0,32 | 0,42 | 0,54 | 0,67 | 0,83 |
| **$R_{min}$ (N)** | 0,31 | 0,39 | 0,50 | 0,63 | 0,78 |
| **ΔR/R (%)** | 3,13 | 7,14 | 7,41 | 5,97 | 6,02 |

Table 1: Values for numerical results of h, h', $R_{ortho}$, $R_{min}$ and relative gain.

The abscissa of Figure 2 represents the initial distance between $N_{ortho}$ and its various neighbour N. As shown in Figure 2 and Table 1, the node $N_{min}$ which has to be stitched to the flap apex with minimal force $R_{min}$ is not the nearest one of the flap apex. It is located a few millimeters forward the flap apex. These finite element results are in contradiction with the ones predicted by the geometrical analysis. It should be noticed that these numerical results are consistent with surgeon's practical experience, which consists in a preliminary stretch of the flap and a stitch point with the nearest point of the opposite edge. Thus the numerical simulation confirms the know-how and intuition of the surgeon. Note that a flap with an θ-value upper than 60° is not used by surgeons because the suture distance at the flap apex is greater than the width of the initial defect.

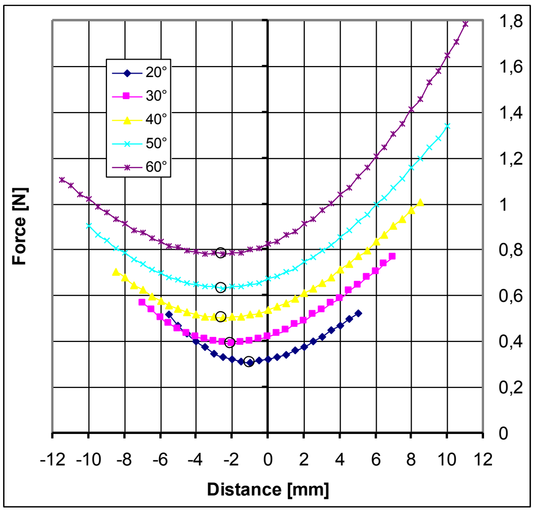


Figure 2: Force necessary to move several points N from the wound edge to the flap apex O'.

By comparing the computed forces to link the neighbour nodes of $N_{ortho}$ to the flap apex, a significant gain is reported in Table 1. This may bring comfort to the patient and sometimes avoid a complication. Taking the flap retraction into account after incision, the optimal stitch ($N_{min}$) corresponds in fact to the orthogonal projection of O (the flap apex position without application of the pre-stress). When the surgeon replaces the flap apex before suturing, he intuitively uses this result.

## 4 Conclusion

The proposed simulations provide new insight into the relationship between the defect size before and after advancement of the V-Y flap in terms of the value of its apex angle. The numerical simulation can bring quantitative information to surgeon in order to choose an optimal geometry of the flap.

## References

[1] Pauchot, J., Chambert, J., Remache, D., Elkhyat, A., Jacquet E. (2012). Geometrical analysis of the V-Y advancement flap applied to a keyston flap. *J Plast Reconstr Aesthet Surg*, **65**, 1087-1095

[2] Pauchot J, Remache D., Chambert J., Elkhyat A. Jacquet E. (2013) Finite element analysis to determine stress fields at the apex of V-Y flaps, *Eur J Plast Surg*, **36**, 185-190

[3] Ogden R.W. (1972). Large deformation isotropic elasticity – on the correlation of theory and experiment for incompressible rubberlike solids. *Proc R Soc Lond A.*, **326**, 565-58